

The Economics of Cold-Climate Electrification

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ABSTRACT

As electric generation continues to decarbonize, customer and utility interest in beneficial electrification has increased. Customers are increasingly looking to replace non-electric equipment with energy efficient electric equipment that reduces point and transport-related emissions, while enabling even deeper decarbonization with customer-sited renewables. In this paper, we provide new data on market saturation of beneficial electrification equipment Xcel Energy's Colorado electric and gas territory. We also provide techno-economic analysis of electrification from customer and utility perspectives, including analysis of incentive, retail rate, and utility avoided cost scenarios. While many of the drivers pushing the early adoption of electrification equipment are non-economic, movement of the technologies into the mainstream will likely require positive returns on investment. We show that absent incentives, "base" or business-as-usual fuel rates will not drive large market shares toward heat pumps and beneficial electrification. Alternative fuel rates, such as those mirroring wholesale rates, or future rates reflecting decarbonization of the grid result in much higher market shares. This effect is stronger when paired with incentive structures that pass utility benefits of electrification to customers through on-bill incentives. These results can be used to draw insights into how other cold-climate territories will electrify, to estimate the potential for electrification in different end-uses by policy makers and program designers, to inform incentive levels, and as quantitative model inputs for cost effectiveness, adoption forecasts, and load forecasting studies.

Introduction

The decarbonization of the electrical grid has increased customer and utility interest in switching from fossil fuels to electricity. Where our study is conducted in Colorado, Xcel Energy has a stated goal of delivering 100% carbon free electricity by 2050, with an interim goal of an 80% carbon free grid by 2030 (Xcel Energy 2021). These regulatory and business shifts towards decarbonized electricity align with customer interest in carbon reduction. Furthermore, technological improvements and cost declines in electric transportation, cooking, water heating, heating, ventilation, and air conditioning (HVAC) have facilitated customer adoption of electric equipment. Heat pumps play a critical role in electrification of most of these end-uses. For HVAC, heat pumps are a combination heating and cooling technology that are promising from the perspective of decarbonization and energy efficiency despite challenges around installation and low regional adoption throughout the United States (Staffel, et al. 2012). World-wide, heat pump installations for HVAC and hot water are increasing rapidly despite barriers, and are most common in new construction (Abergel 2021). Heat pumps use electricity as their primary fuel and have a variety of configurations (air-source, ground-source, water-source). For water heating end-uses, heat pumps have been well studied in residential (Hoeschele 2013) and commercial

(Zogg 2005) applications. Because of their high efficiency and ability to absorb heat from the outside environment, heat pumps can reduce emissions, energy usage, and increase end-user comfort. Because of the benefits in carbon reduction, customers using heat pumps to switch from fossil fuels to electricity can be considered beneficial electrification (Farnsworth 2019).

Although national data on heat pump adoption levels are not readily available, penetration in the United States is far below Europe and Asia, in part due to cheap and available natural gas. Efficient saturation of air-source heat pump technology in the American Southwest was estimated at 20% (Kolwey 2018). It is likely to be much lower in other parts of the country with less new construction and air conditioning need. Significant economic, regulatory, policy and public acceptance (informational) issues have been cited as barriers for adoption (Gaur 2021), although the economic and informational are arguably the most important (Dymond, et al. 2018).

Some investigation of cold-climate heat pumps in various configurations has been done, for example in Canada (Hakkaki-Fard 2015), and China (Zhang 2017). Retrofit economics have been studied in the United Kingdom (Kelly 2011). While favorable customer economics are common when the existing (baseline) technology is an electric furnace and an existing AC unit is at end-of-life (S. a. Nadel 2016), the economics tend to be worse when the baseline technology is a natural gas furnace used in a cold climate (S. Nadel 2016), (Edwards 2018). Ductless mini-split heat pumps have been found to be cost effective in some cold climates for new construction applications, especially when combined with heat-pump water heaters (Kolwey 2018).

Because of the large opportunity in electric energy and demand savings when replacing an existing electric furnace or water heater, heat pumps have a long-standing place in utility energy efficiency programs that offer rebates for the purchase of efficient equipment (Berry 1983). Incentives for fuel switching are more controversial, as they may involve multiple actors (when the natural gas utility is different than the electric utility, for example), but have nonetheless been found to increase adoption (Sparn 2021).

In this paper, we model the operation and economics of nine different heat pump configurations for both residential and commercial, from both the customer perspective and the utility perspective. We then combine the resulting customer economics with customer preference modeling solicited from an original primary data collection effort. Incentives to the customer are modeled in a stream of on-bill payments designed to align utility and customer benefits by increasing the customer savings over the lifetime of the equipment. The outcome is an estimate of long-run heat pump market share for commercial and residential applications for three different scenarios around rates and utility avoided costs, and a continuous vector of incentives.

Modeled Beneficial Electrification Measure Configurations

For both the residential and commercial sectors, we modeled central air-source heat pumps and ductless heat pumps (DHPs) as these are the most commonly installed and universally applicable heat pumps. There are several different baseline considerations for each of these measures, including furnaces and boilers with and without AC. For the residential sector,

we also modeled a gas-storage water heater to heat-pump water heater (HPWH) measure. For the commercial sector, a RTU to central air-source heat pump measure was also included.

The two tables on the next page provide details on the characteristics for each measure, including:

- Baseline and efficient measure definitions
- Normalizing units
- Electric energy consumption in kWh (baseline and efficient)
- Natural gas consumption in therms (baseline and efficient)
- Baseline and efficient measure costs

Table 1 provides the characteristics for the residential measures, using the characteristics of a single-family home as an example in the table.

Table 2 provides the characteristics for the commercial measures, using the characteristics of an office as an example in the table. The source of the savings and costs come from Xcel Energy Colorado's 2021-2022 DSM Plan and are combinations of different energy efficiency measure characteristics.

The DHP measures are assumed to be partial displacement of the baseline gas measures, while the central heat pump and HPWH measures are full displacement of the baseline gas measures. The DHP partial displacement measures are assumed to displace 50% of the natural gas heating load. Additionally, the baseline natural gas equipment is assumed to be replaced by higher efficiency natural gas equipment, therefore the efficient consumption for these measures is not simply 50% of the baseline gas load.

Table 1. Residential Beneficial Electrification Measure Characteristics*Single family home characteristics shown as an example*

Measure Name	Baseline Definition	Efficient Definition	Units ¹	Baseline Consumption (kWh)	Efficient Consumption (kWh)	Baseline Consumption (Therms)	Baseline Consumption (Therms)	Baseline Equipment Cost	Efficient Incremental Cost ²
Res - Gas Furnace + AC to Central HP	80% AFUE gas furnace + AC	Central HP < 17 SEER	per ton	532.1	2651.3	172.7	0.0	\$690.98	\$1,178.52
Res - Gas Boiler + AC to Central HP	Standard Boiler (80% AFUE) + AC	Central HP < 17 SEER	per ton	532.1	2651.3	154.2	0.0	\$828.15	\$1,178.52
Res - Gas Furnace to Central HP	80% AFUE gas furnace	Central HP < 17 SEER	per ton	0.0	2651.3	172.7	0.0	\$268.13	\$1,178.52
Res - Gas Boiler to Central HP	Standard Boiler (80% AFUE)	Central HP < 17 SEER	per ton	0.0	2651.3	154.2	0.0	\$405.30	\$1,178.52
Res - Gas Furnace + AC to Gas Furnace + Ductless Mini Split	80% AFUE gas furnace + AC	95% AFUE gas furnace + Ductless Mini Split (SEER 18-23)	per ton	532.1	1463.7	172.7	72.7	\$690.98	\$3,580.65
Res - Gas Boiler + AC to Gas Boiler + Ductless Mini Split	Standard Boiler (80% AFUE) + AC	HE Boiler 95% AFUE + Ductless Mini Split (SEER 18-23)	per ton	532.1	1463.7	154.2	68.2	\$828.15	\$3,978.82
Res - Gas Furnace to Gas Furnace + Ductless Mini Split	80% AFUE gas furnace	95% AFUE gas furnace + Ductless Mini Split (SEER 18-23)	per ton	0.0	1463.7	172.7	72.7	\$268.13	\$3,580.65
Res - Gas Boiler to Gas Boiler + Ductless Mini Split	Standard Boiler (80% AFUE)	HE boiler 95% AFUE + Ductless Mini Split (SEER 18-23)	per ton	0.0	1463.7	154.2	68.2	\$405.30	\$3,978.82
Res - Gas Storage WH to HPWH	Standard Gas storage water heaters	Heat Pump Water Heater	water heater	0.0	1836.1	375.9	0.0	\$1,090.99	\$2,073.13

¹ Units, when described as “per ton” and in nominal capacity.² Efficient costs incremental to the cost of new replacement of baseline equipment. Costs include installation, but not complex installation circumstances, for example requiring the upgrade of the electrical panel.

Table 2. Commercial Beneficial Electrification Measure Characteristics*Office characteristics shown as an example*

Measure Name	Baseline Definition	Efficient Definition	Units	Baseline Consumption (kWh)	Efficient Consumption (kWh)	Baseline Consumption (Therms)	Baseline Consumption (Therms)	Baseline Equipment Cost	Efficient Incremental Cost
Com - Gas Furnace + AC to Central HP	80% AFUE gas furnace + AC	Central HP < 17 SEER	MBH Input	130.1	174.4	11.9	0.0	\$19.95	\$122.92
Com - Gas Furnace to Central HP	80% AFUE gas furnace	Central HP < 17 SEER	MBH Input	0.0	174.4	11.9	0.0	\$9.42	\$122.92
Com - Gas Boiler + AC to Central HP	Standard Boiler (80% AFUE) + AC	Central HP < 17 SEER	MBH Input	130.1	174.4	15.1	0.0	\$19.95	\$122.92
Com - Gas Boiler to Central HP	Standard Boiler (80% AFUE)	Central HP < 17 SEER	MBH Input	0.0	174.4	15.1	0.0	\$9.42	\$122.92
Com - Gas Boiler + AC to Gas Furnace + Ductless Mini Split	Standard Boiler (80% AFUE) + AC	HE Boiler 95% AFUE + Ductless Mini Split (SEER 18-23)	MBH Input	130.1	112.3	15.1	6.3	\$19.95	\$303.11
Com - Gas Furnace + AC to Gas Furnace + Ductless Mini Split	80% AFUE gas furnace + AC	95% AFUE gas furnace + Ductless Mini Split (SEER 18-23)	MBH Input	130.1	112.3	11.9	5.3	\$19.95	\$297.57
Com - Gas Boiler to Gas Furnace + Ductless Mini Split	Standard Boiler (80% AFUE)	HE Boiler 95% AFUE + Ductless Mini Split (SEER 18-23)	MBH Input	0.0	112.3	15.1	6.3	\$9.42	\$303.11
Com - Gas Furnace to Gas Furnace + Ductless Mini Split	80% AFUE gas furnace	95% AFUE gas furnace + Ductless Mini Split (SEER 18-23)	MBH Input	0.0	112.3	11.9	5.3	\$9.42	\$297.57
Com - Gas RTU to Central HP	DX RTU Unit 10-13 EER	Central HP < 17 SEER	Ton	1077.5	2093.2	134.1	0.0	\$226.30	\$1,475.03

Technical Potential

Technical potential is defined as the total potential in the market regardless of market or economic barriers. Technical potential is essentially the amount of savings that could be achieved if every piece of baseline equipment was replaced immediately with efficient equipment. For the purposes of this exercise, we looked only at technical and economic potential outputs, rather than market potential adoption. However, we do look at customer economics and willingness to pay curves to estimate what market adoption *could* look like under different scenarios. These considerations are further discussed later in this report.

Technical potential in our model considers the total density of equipment, the percent that is baseline versus efficient, and the percent that is suitable to be replaced by the efficient equipment. The density represents the average number of the measure units per the scaling basis of the sector.

For residential, the scaling basis is “per home,” meaning the number of units per home or, as in the case of heat pumps, the average number of tons per home. For commercial, the scaling basis is typically “per 1,000s of sq ft of floorspace.” In the case of commercial heat pumps in the tables above, we use average MBH input per 1,000 sq ft of commercial floorspace by building type. Table 3 below provides the baseline densities for single family homes in residential and office buildings in commercial as examples of the inputs.

Table 3. Gas Measure Densities

Baseline Measure	Building Type	Common Units	Scaling Basis	Density
Res - Gas Furnace	Single Family Home	Tons	per Home	3.15
Res - Gas Boiler	Single Family Home	Tons	per Home	0.14
Res - Gas Storage WH	Single Family Home	Water Heaters	per Home	0.86
Com - Gas Furnace	Office	MBH Input	per 1,000 Sq. Ft.	13.75
Com - Gas Boiler	Office	MBH Input	per 1,000 Sq. Ft.	5.02
Com - Gas RTU	Office	Tons	per 1,000 Sq. Ft.	3.37

Density is the units (scaling basis) per customer. The total density for each measure is multiplied by the building stock, percent of the equipment that is currently the baseline, and the percent suitable to get to the total technical potential for each measure. For beneficial electrification, the density is 1.0 since there needs to be baseline equipment in place to be considered “beneficial”. Also, the percent of stock equipment that is currently the baseline is 100%, since only gas equipment is counted in the stock. In calculating the technical potential, only the competing measure with the highest savings potential is used to avoid any double counting.

A common way to view and understand the magnitude of potential savings is the potential savings as a percent of the total utility sales (both actual and forecasted). This is quite a

useful view on the beneficial electrification side since there are so few end-uses for natural gas. In this way, it is relatively easy to look at the percent of sales metrics to see if the results are reasonable. Figure 1 shows the BE technical potential as a percent of Xcel Energy Colorado gas sales for the residential and commercial sectors.

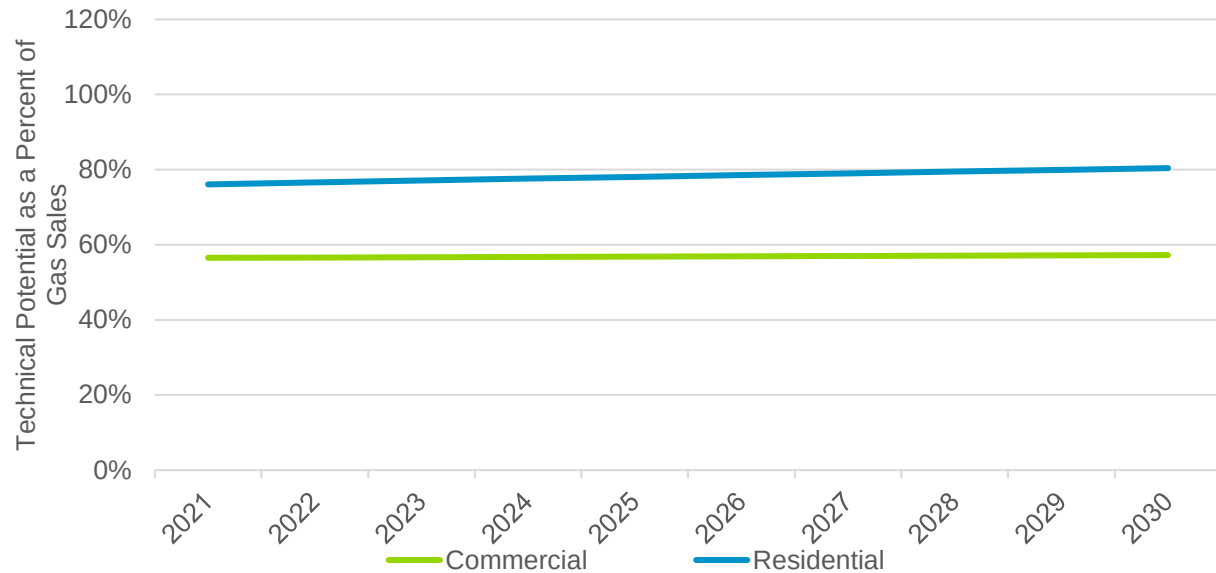


Figure 1. Heat pump beneficial electrification technical potential as a percent of Xcel Colorado gas sales across all residential segments and all commercial segments. Future sales are as projected by Xcel Energy.

We compared the technical potential results to EIA’s Residential Energy Consumption Survey (RECS 2015) and Commercial Building Energy Consumption Survey (CBECS 2012) shares of end use loads for natural gas. In residential, space and water heating make up over 95% of the total natural gas consumption according to RECS. Our measure list is not exhaustive (for example we are not looking at electric cooking, clothes drying, and other miscellaneous measures) and does not include any secondary space heating measures, and only partial displacement of gas for the DHP measures³, so our result of about a 75-80% reduction in total residential natural gas load is reasonable. In commercial, we limit the study to HVAC measures only (no water heating, cooking, etc.) and EIA’s CBECS shows that on average over all commercial building types, space heating makes up about 60% of total natural gas load. Therefore, our modeled technical potential results of about 55% for commercial is also reasonable.

Customer Economics: Willingness to Pay

As mentioned above, one of the barriers to mainstream heat pump adoption is customer economics. To go through installation and fuel switching, most customers expect the technology

³ Secondary or dual-fuel heating is common in heat-pump applications and we did not examine secondary heating replacement, or full replacement for ductless heat pump measures. Though we did not compare end-use gas consumption in detail with RECS, this likely explains the majority of the remaining 15% discrepancy, since 100% of water heating gas consumption can be replaced by heat pump water heaters.

to pay for itself over the lifetime of the equipment. Ignoring the time value of money (which many customers do), this can be represented by the simple payback period P , which is the number of years of annual bill savings S (positive cash flow) required to recoup an initial cost $CapEx$ of the beneficial electrical technology BE investment less the cost $CapEx$ of the baseline technology B (negative cashflow):

$$P = \frac{CapEx_{BE} - CapEx_B}{S}$$

To determine customer expectation around payback, we conducted primary research where 1,755 residential and 267 commercial participants were surveyed about their willingness to switch from gas to electric equipment. Participants were only asked about replacing baseline equipment currently installed at their home or business. For each applicable equipment type, participants were provided with estimated annual bill savings, incremental cost of new equipment including utility incentives, and a calculated payback. They were then asked if they would consider purchasing the equipment with those parameters. If a participant would consider purchasing equipment, they were asked the question again with a higher incremental cost and longer payback period. If participants would not consider purchasing, they were asked the question again with a lower incremental cost and shorter payback. By repeating this until a participant's response changes, we determine the longest payback at which a respondent would consider beneficial electrification for each equipment type. To reduce bias, we chose a randomized discrete starting value from a range of reasonable equipment costs as a starting point for each participant. It should be noted that some customers were not willing to adopt beneficial electrification technologies at any payback. This creates the y-intercept of the payback function.

By aggregating and fitting statistical models to the responses, we end up with the payback response shown for select technologies and customer segments in Figure 2. To interpret these models, simply identify a desired long-run market share (the percentage of customers that would be willing to adopt given full awareness of the technology) on the y-axis, and lookup the corresponding value on the x-axis. This is the payback period required to saturate the market to the desired percentage after full stock turnover.

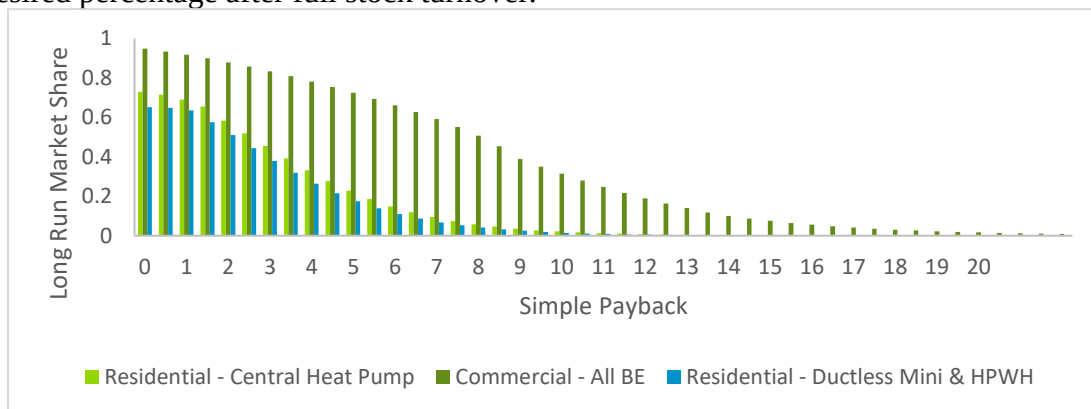


Figure 2. Solicited customer payback response for select technologies by residential single family and commercial office customers. Reasons for the differences between residential and commercial were not examined in the survey instrument.

Economics: Value Streams

The economics of heat pumps can be expressed in terms of the different cashflows affecting each actor in the system. The primary actors are the electric utility, the gas utility, and the customer. We use the mTRC, UCT, and PCT⁴ as the primary tests to evaluate the economics of each technology. Each of these tests expresses the benefits of a measure divided by the costs and is expressed as a fraction. PCT represents the economics from the customer's perspective, the UCT represents the economics from the utility or program administrator's perspective, and the mTRC is designed to represent the economics from program participant and non-participants perspectives. **Table 5** shows cash flow streams for "Business as Usual" conditions whereby all incentives and program administration costs are removed. The table illustrates the cash flows for residential single family and commercial office applications in Xcel Energy's Colorado territory. Other incentive scenarios are addressed below. **Table 4** illustrates the definitions of each relevant value stream by cost test.

Table 4. Value Stream Definitions by Cost Test

Cost Test	Bill Savings / Lost Revenue	Incremental Costs	Utility Avoided Costs	Incentives
UCT	-	-	Benefit	Cost
mTRC	-	Cost	Benefit	Transfer
PCT	Benefit	Cost	-	Benefit

Table 5 shows that while some commercial measures promise to be cash-flow positive to the customer (specifically, those with both heating and air conditioning), the higher cost of electricity as a fuel makes the residential measures cash flow negative to the customer. Negative values are possible for many of the value streams. For example, a negative bill savings value represents increased annual fuel cost to operate the heat pump. Except for those applications without baseline air conditioning, all measures are cashflow positive from the utility perspective – reflecting a lower cost to the grid after electrification. These avoided costs include the expected compliance cost of CO₂ emissions in Colorado.

Table 5. BAU 2022 Net Present Value Streams⁵ for Heat Pump Measures

Measures	Net Lost Revenue / Bill Savings from Fuel Switching	Incremental Equipment Costs ⁶	Utility Avoided Costs
Com - Gas Boiler + AC to Central HP	\$84.88	\$(105.55)	\$192.39
Com - Gas Boiler + AC to Gas Furnace + Ductless Mini Split	\$112.69	\$(290.25)	\$195.11
Com - Gas Boiler to Central HP	\$(102.49)	\$(116.34)	\$(42.85)
Com - Gas Boiler to Gas Furnace + Ductless Mini Split	\$(74.68)	\$(301.04)	\$(40.13)

⁴ Modified Total Resource Cost Test, Utility Cost Test, and Participant Cost Test. See CA SPM for details (California Energy Commission 2001).

⁵ Value streams are presented *per unit*, for example, per ton for the Residential Gas Furnace + AC replacement with Central Heat Pump measure. See Table 1 and Table 2 for measure unit definitions. All cash flows are net present values.

⁶ Incremental equipment costs are total additional cost over baseline new replacement per unit.

Com - Gas Furnace + AC to Central HP	\$51.12	\$(105.55)	\$136.03
Com - Gas Furnace + AC to Gas Furnace + Ductless Mini Split	\$90.20	\$(284.57)	\$157.55
Com - Gas Furnace to Central HP	\$(136.25)	\$(116.34)	\$(99.21)
Com - Gas Furnace to Gas Furnace + Ductless Mini Split	\$(97.17)	\$295.36)	\$(77.69)
Com - Gas RTU to Central HP	\$(183.89)	\$(1,279.95)	\$1,674.87
Res - Gas Boiler + AC to Central HP	\$(2,528.52)	\$(359.13)	\$330.83
Res - Gas Boiler + AC to Gas Boiler + Ductless Mini Split	\$(1,058.40)	\$(3,229.43)	\$494.92
Res - Gas Boiler to Central HP	\$(3,504.32)	\$(792.56)	\$(208.72)
Res - Gas Boiler to Gas Boiler + Ductless Mini Split	\$(2,152.50)	\$(3,662.85)	\$(98.14)
Res - Gas Furnace + AC to Central HP	\$(2,365.62)	\$(499.73)	\$628.37
Res - Gas Furnace + AC to Gas Furnace + Ductless Mini Split	\$(828.01)	\$(2,961.91)	\$663.23
Res - Gas Furnace to Central HP	\$(3,341.42)	\$ (933.15)	\$88.82
Res - Gas Furnace to Gas Furnace + Ductless Mini Split	\$(1,803.82)	\$(3,395.33)	\$123.68
Res - Gas Storage WH to HPWH	\$(430.22)	\$(1,006.69)	\$2,928.11

There is little economic motivation for most customers with the studied baseline technologies to switch to heat pumps without significant utility intervention in the form of incentives or rate design modification. In the simplest terms, there has been such limited adoption of heat pumps to date because the customer economics in mainstream retrofit applications like the ones examined here are not favorable.

We can see from Table 5 that under base scenario conditions the high avoided costs in the cash-flows show that utilities stand to benefit from customers switching from gas heating to electric heating with heat-pumps. This benefit suggests that it can be beneficial for utilities to pass some of those benefits to customers in the form of incentives. Figure 3 illustrates how the customer annual bill savings change in the BAU scenario for one commercial measure (Central heat pump replacing RTU) in two segments, as a fraction of the utility avoided cost benefit is passed to the customer as a bill credit incentive. By comparing the payback period of each technology under each bill credit incentive to the solicited expectation on payback, we estimate the long run market share for each technology and customer segment under different scenarios.

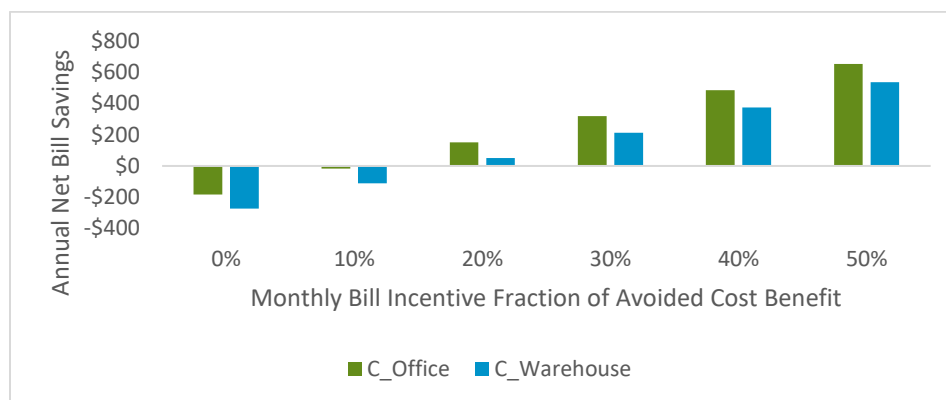


Figure 3. Net bill savings on the y-axis for central heat pumps replacing gas RTUs for two segments as monthly incentives are added. X-axis shows the incentive amount as a fraction of the annual utility avoided cost in the BAU scenario

Scenario Summary

To demonstrate the range of beneficial electrification economics under different economic conditions, the team ran three scenarios around retail rates and utility avoided costs, summarized below:

1. Base: In the “base” scenario we assume that the avoided cost of electricity and gas are as forecasted by Xcel Energy and that customers pay the forecasted retail rate for electric and gas service. The utility avoided costs include the compliance cost of CO₂ emissions.
2. Near-future: In the “near future” scenario, we use the forecasted gas and electric avoided costs and retail rates for 2030, and pass the compliance cost of CO₂ emissions into retail rates, driving up the cost. This scenario is more favorable to the adoption of beneficial electrification than the base scenario because the cost of gas is higher and the cost for electricity is lower in the future, especially when accounting for compliance costs of CO₂. Intuitively, as the grid decarbonizes, beneficial electrification becomes more attractive.
3. Decarbonized grid: Our last scenario examines the economics of beneficial electrification if the grid was fully decarbonized and retail customers were paying a wholesale rate (equal to the utility avoided cost). Because it represents very favorable economic conditions for beneficial electrification, this scenario represents an upper bound of expected long run market share of the selected measures.

Each of the scenarios includes the expected compliance cost for CO₂ in the utilities avoided costs. Thus, as the grid decarbonizes the utilities avoided costs for delivering electricity decreases. Though it is possible that widespread adoption of heat pumps count shift peak hours, we did not examine this possibility. These three scenarios represent a spectrum of economic conditions for the utility and the customer. Each of these three scenarios produce vastly different results in terms of long run market share for beneficial electrification technologies. In general, under current conditions, the utility economics for beneficial electrification are more favorable than customer economics. This provides an environment where utility incentives to customers can create a win-win situation for both parties. To explore this idea, we present the long run

market share of technologies in relationship to the fraction of utility avoided costs transferred to customers via incentives for each scenario in the following section.

Market Share: Base Scenario

As Figure 3 demonstrated, the transfer of avoided costs benefits to customers in the form of incentives can make heat pumps economical for the customer by driving down the payback. In this section, we model the potential market shares that can result by passing a monthly incentive to customers after installation of a heat pump, making a positive payback on the investment possible, as shown for 2022 in Figure 4 below. Note that the asymptotes of the curves are defined by the market shares at instantaneous payback, shown in Figure 2. Therefore, the curves flatten out for more economic measures as incentives increase, especially in the “near-future” and “decarbonization” scenarios.

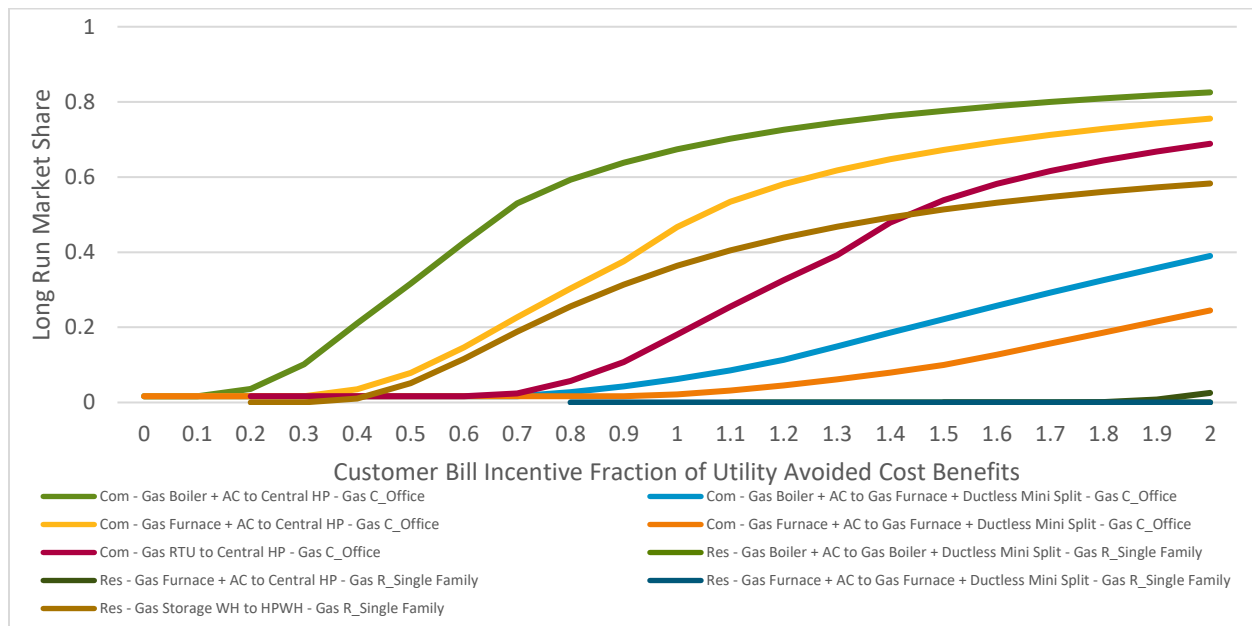


Figure 4. Long run market share by beneficial electrification measure for single family residential and commercial office customer segments in the Base scenario. Measures with no payback are not shown.

Note that the market shares are mostly quite low. Even passing 30% of utility avoided cost benefits to customers as an on-bill incentive results in just over 10% market share for the most attractive measure (Gas Boiler with AC switching to Central Heat Pump). This is because the large negative cashflows are not easily offset by the bill savings to the customer - the retail rates for electricity are too high relative to the gas retail rate to make electrification attractive. For wide scale adoption of these technologies, the economic conditions need to change with time, policy intervention (e.g., additional incentives, changes to rates), or both. We can create more favorable economic conditions by setting the retail rate equal to the avoided cost rate.

Market Share: Near-Future Scenario

Recall that in the “near future” scenario, rates are set out to forecasted 2030 values. At this point, the increased decarbonization of the grid has more or less offset increasing costs of electricity supply, while the compliance cost of carbon has driven up the retail rate and utility avoided cost of gas. These two factors make fuel switching and on-bill incentives more valuable and attractive. As a point of comparison, in the “near future” scenario, our most attractive measure (Gas Boiler with AC switching to Central Heat Pump) has a market share of 75% up from 10% in our base scenario. Figure 5 shows that most of our measures have at least some expected market share under the economic conditions provided by the “near future” scenario.⁷

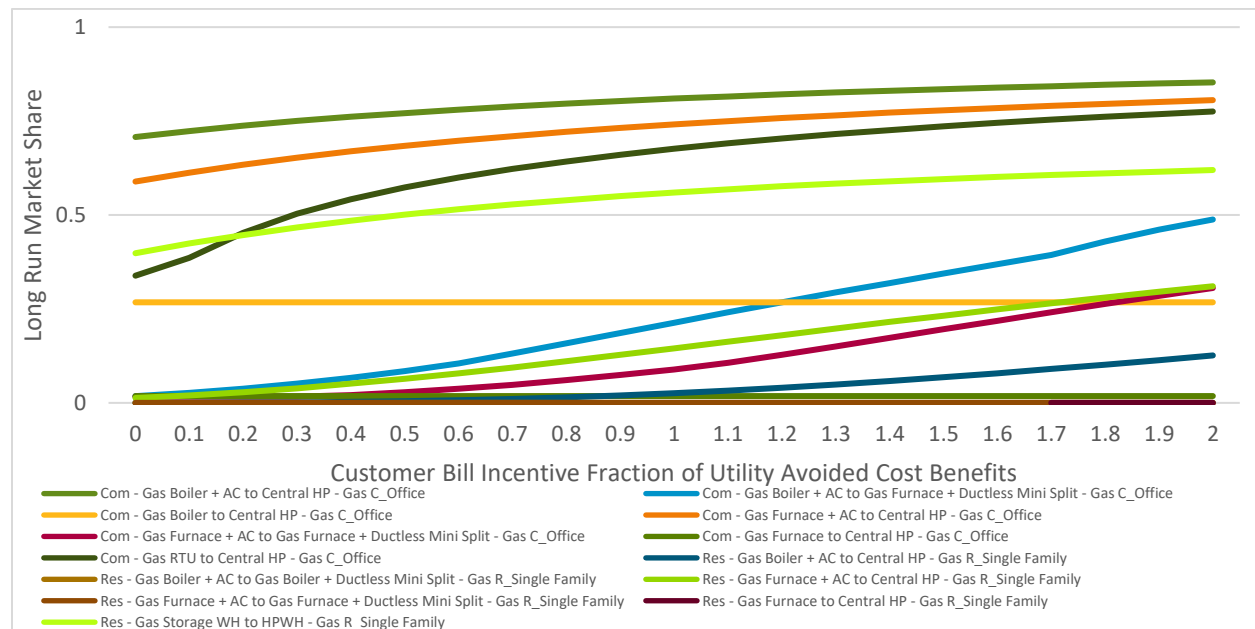


Figure 5. Long run market share by beneficial electrification measure for single family residential and commercial office customer segments in the “near future” scenario. Measures with no payback are not shown.

Market Share: Decarbonization Scenario

As explained above, the “decarbonization” scenario shows the effects of the compliance cost of CO₂ emissions after the electric grid has fully decarbonized, as well as passing wholesale rates to beneficial electrification customers. In this environment, most of the heat pump technologies, especially those with an existing air conditioner in the baseline, generate substantial bill savings (and thus attractive payback periods) to customers even absent incentives. Figure 6 shows the modeled market shares for the heat pump technologies in this scenario as a function of increasing incentives. Many of the curves are relatively flat, as the payback curves are already past their inflection points, and additional incentives experience diminishing marginal returns. Notably, the market shares for commercial ductless mini-splits with AC

⁷ The Com - Gas Boiler to Central HP measure has a constant market share in this scenario because it has negative utility avoided cost benefits in this scenario. In this case the incentive was held at 0.

baselines increase much more for increasing incentives since they have lower bill savings and lower resulting market shares when the customer bill incentive fraction as a percentage of utility avoided costs is 0 (Figure 6).

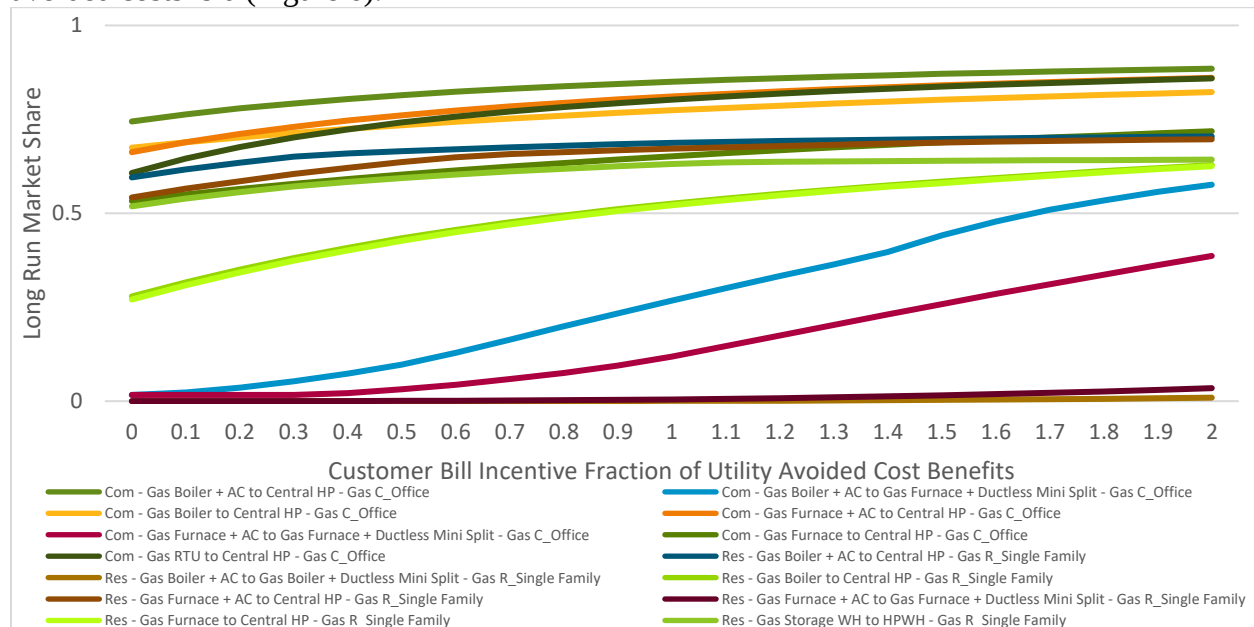


Figure 6. Long run market share by beneficial electrification measure for single family residential and commercial office customer segments in the “decarbonization” scenario. Measures with no payback are not shown.

Conclusion

Beneficial electrification in cold climates provides opportunities to reduce greenhouse gasses as the grid decarbonizes. There is the opportunity to technically replace 60% of commercial gas use, and nearly 80% of residential gas use through the heat pump technologies modeled in this study. Depending on avoided cost rates, electric and gas utilities may have large benefit streams associated with electrification through heat pumps, making these initiatives a valuable part of customer demand-side management programs. Wide-scale adoption of beneficial electrification technologies, like the heat pumps studied here, is dependent on favorable economic conditions for residential and business customers. Under business-as-usual (“base”) conditions in Xcel Energy’s territory in Colorado, absent incentives, beneficial electrifications are unlikely to achieve high levels of penetration due to upfront cost and negative bill savings on fuel after electrification. Our scenario analysis shows that future conditions, especially when coupled with a compliance cost of carbon and special beneficial electrification retail rates can dramatically improve the economics to customers, and thus the long-run market share for heat pump technologies. These economics can be further improved as utilities may have the opportunity to shift avoided costs to consumers via incentives, tipping the economic scales for consumers and enabling higher market shares for beneficial electrification measures. Even under favorable economic conditions, including incentives, our primary research shows that some customers will not adopt beneficial electrification technologies due to non-economic barriers. Customer preference modeling suggests that currently, depending on technology and customer segment, between 20% and 40% of customers would not be willing to adopt beneficial

electrification technologies even under highly favorable economic conditions. This suggests that additional customer outreach and education may be required in tandem with incentives. We hope that utilities, policy makers, and customers will use the information provided to discuss the goals and barriers to beneficial electrification.

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